Universidade de Aveiro Escola Superior de Saúde da Universidade de Aveiro

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Valores normativos pediátricos para o Teste de Marcha com Carga Progressiva

Paediatric normative values of the Incremental Shuttle Walking Test

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Paediatric normative values of the Incremental Shuttle Walking Test

Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Fisioterapia, realizada sob a orientação científica da Doutora Alda Marques, Professora Adjunta da Escola Superior de Saúde da Universidade de Aveiro.

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Palavras-chave Teste de marcha com carga progressiva modificado; População pediátrica; Valores de referência; Regressão estatística

Sumário

Enquadramento: O teste de marcha com carga progressiva modificado (TMCPm) tem sido largamente utilizado na população pediátrica. No entanto os valores de referência precisam de ser solidamente estabelecidos de forma a diferenciar a normalidade do que deve ser patológico. Este estudo teve como objetivo contribuir para o estabelecimento de valores de referência do TMCPm na idade pediátrica determinando quais as variáveis (antropométricas, demográficas e clínicas) que influenciam a distância percorrida no teste e estabelecer uma equação de referência de forma a prever os valores do teste para esta população.

Métodos: Cinquenta e cinco crianças saudáveis participaram num estudo transversal onde realizaram dois TMCPm num corredor de 10 metros. Foram utilizados protocolos padronizados para a medição dos dados antropométricos e demográficos, da atividade física, espirometria e da força muscular do quadricípite (FMQ).

Resultados: De uma forma geral as crianças saudáveis caminharam uma média de 1233.82±348.86 metros no TMCPm, apresentando uma larga variabilidade (340-2250 m). A distância percorrida no TMCPm correlacionou-se significativamente com o género ($r=0.274$; $p=.043$), com a idade ($r=0.659$; $p<0.001$), com o peso ($r=0.310$; $p=.021$), com a altura ($r=0.646$; $p<.001$), com a escala da atividade física ($r=0.284$; $p=.035$), com a FMQ ($r=0.535$; $p<.001$), mas não com o índice de massa corporal ($r=-0.026$; $p=.852$) ou com a % predita do volume expiratório forçado no primeiro segundo ($r=0.152$; $p=.267$). O modelo de regressão linear múltipla evidenciou que o género, a idade, o peso e a FMQ influenciam de forma independente o TMCPm em crianças saudáveis, e explicam uma variabilidade de 70% ($p<0.001$). Desta forma chegou-se a equação de referência : $TMCPm_{preditiva}$= -699.69+(239.329*género)+(134.616*idade)-(9.941*peso)+(12.107*FMQ), where male gender = 1 and female gender = 0.

Conclusão: A variabilidade do TMCPm é explicada em grande parte pelo género, idade, peso e FMQ. A equação de referência poderá ser útil para a interpretação da performance realizada no TMCPm na população pediátrica.

Keywords Incremental Shuttle Walking Test; Paediatric Population; Reference value; Statistical regression

Abstract

Background: Reference values for the incremental shuttle walking test (ISWT) which is applicable in the paediatric population to prescribe exercise need to be solidly established. This study aimed to contribute for establishing paediatric reference values of the ISWT and a reference equation for predicting ISWT.

Methods: In a cross-sectional study, 55 healthy children performed two ISWT in a 10-m long corridor. The anthropometric and demographic data, physical activity, spirometry and quadriceps muscle strength (QMS) were measured using standardized protocols.

Results: In general, healthy children walked 1233.82±348.86 meters in the ISWT, presenting large variability (range 340-2250 m). There were significant correlations between the distance walked in the ISWT with gender (r=0.274; p=.043), age (r=0.659; p<0.001), weight (r=0.310; p=.021), height (r=0.646; p<.001), PAS (r=0.284; p=.035), quadriceps muscle strength (r=0.535; p<.001), but not with BMI (r=-0.026; p=.852) or with FEV1 % predicted (r=0.152; p=.267). A model of stepwise multiple regression showed that gender, age, weight and QMS were independent contributors to the ISWT in healthy subjects, explaining 70% (p<0.001) of the variability. The derived reference equation was: $ISWT_{predicted}$= -699.69+(239.329*gender)+(134.616*age)-(9.941*weight)+(12.107*QMS), where male gender = 1 and female gender = 0.

Conclusion: In conclusion, the variability of the paediatric ISWT was explained largely by gender, age, weight and QMS. The reference equation could be useful for interpreting the walking performance of paediatric population.

Abbreviations

QMS – Quadriceps Muscle strength

ISWT – Incremental shuttle walking test

6MWT – 6-min walking test

6MWD – 6-min walking distance

ISWD – Incremental shuttle walking distance

ICF – International Classification of Functioning, Disability and Health

PA – Physical Activity

FVC - Forced vital capacity

FEV_1 - Forced expiratory volume in the first second

MMT - manual muscle testing

HHD - hand-held dynamometer

HR – Heart Rate

mBS – modified Borg Scale

BMI – Body mass index

R^2 – R-Squared

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Introduction

The evaluation of physical abilities and its clinical consequences are key elements in pulmonary rehabilitation and an important issue in routine clinical practice when working with adults or children(1); to assess patient's ability to exercise (determining the level of work for exercise training), to test the effectiveness of the treatment (obtaining comparative information before and after an exercise training program) and to ensure patient's safety (1, 2). There are two main types of obtaining these information, i.e., via maximal test in a laboratory testing using a cycle ergometer or treadmill or performing a field test(1). Each type offers advantages and disadvantages(1).

Determination of aerobic capacity is ideally performed in an exercise testing laboratory using specialized equipment and maximal exercise protocols on either a treadmill or a cycle ergometer to measure maximal oxygen consumption (VO2max) (3-5). This is considered the 'gold standard' measurement of cardiorespiratory fitness (3-5). However, many professionals who prescribed exercise such as physiotherapists, do not work in clinical settings where all patient's safety required to perform a maximal exercise test can be ensured and frequently do not have access to treadmills or cycle ergometers with capacity to perform maximal tests. Therefore, field tests requiring minimal equipment are ideal. There are several field tests such as (6), 6-min Walk Test (6MWT)(7), 12-min Walking Distance(8), 20-m Shuttle Run Test(9), Endurance Shuttle Walk Test(10) and Incremental Shuttle Walking Test (ISWT)(11). From all of these, the 6MWT is the most popular of the field walking tests as it is simple to perform and low cost (12, 13). However, the main disadvantage of the 6MWT is to allow patients to set their walking speed. As an alternative to self-paced tests and in an attempt to improve standardization and reproducibility, the ISWT was developed by Singh et al. (11). The greatest advantage of the ISWT is that, due to this difference, the incremental shuttle walk distance (ISWD) correlates more strongly with maximal oxygen uptake than the 6-min walk distance (6MWD) (12, 14, 15).

The ISWT is a field test which provides reliable and valid data and correlates with the individual's aerobic capacity, and therefore, can be used in most clinical settings with many populations(3, 4, 16-19). It has become an established and widely used measure of exercise capacity, especially in adult patients with cardiopulmonary disease(20). However, given its advantages already discussed and to the fact of being a test externally paced it has been argued that offers increased motivation to subjects, removes tester influence and is more representative of patterns of daily childhood (21). Therefore, several studies have applied this test to paediatric populations (<18 years) with asthma

(22) and cystic fibrosis (23, 24) to evaluate their physical performance. However, to be able to consider data obtained from patients as clinically relevant, reference values from the healthy populations are crucial.

In relation to the adult population (18 to 83 years old), an equation was developed recently (25), demonstrating a strong reliability ($r= 0.85$, $p<0.0001$) (25). However, to the best of our knowledge there are no reference values for the healthy paediatric population (<18 years old). This may lead to imprecise diagnosis and affect paediatric treatment and monitoring.

Hence, the aim of this study was to contribute for establishing healthy paediatric reference values of the ISWT and a reference equation for predicting ISWT.

Methods and materials

Study Design and Ethics

A cross-sectional study was conducted in Portugal (North and Central regions). The study was approved by the Ethics Committee of the Research Unit of Health Sciences at the School of Nursing in Coimbra (P186-10/2013). The involved institutions gave written approval and informed consent was obtained from all participants and legal representatives prior to any data collection (26).

Recruitment and Participants

A school of music (Banda Filarmónica Ovarense) and a basketball club (Esgueira Basketball club) were first contacted and written information about the study was provided. These institutions, contacted the researcher who arranged a meeting to provide detail explanation about the study. After obtaining institutions written approval, potential eligible participants were identified by the institution manager.

The researcher contacted a convenience sample of 55 healthy children aged 5 to 18 years old, who fulfilled the inclusion criteria to participate.

Participants were included if they were between 5-18 years old and did not have any severe and/ unstable disease which could limit the exercise tolerance (cardiac or respiratory diseases and significant musculoskeletal disorders). Participants were excluded if they presented at least one of the following criteria: i) signs of cognitive impairment; ii) were unable to understand or perform

any procedure during the protocol; iii) respiratory disorders (nasal obstruction, asthma, bronchitis, rhinitis, laryngopathy and respiratory tract infections); iv) cardiac diseases; v) metabolic, neuromuscular or musculoskeletal disease and vi) signs of drug and/or alcohol consumption.

Data collection

A structured questionnaire based on the International Classification of Functioning, Disability and Health (ICF) Checklist (27) was first used to collect socio-demographic information (gender, date of birth) from children and their legal representative (level of education and marital status) and anthropometric (weight and height to calculate the body mass index) data only from children. A questionnaire to investigate the practice of any regular physical activity was then completed from all children. Then, spirometry was performed to ensure normal lung function (forced vital capacity (FVC), forced expiratory volume in the first second (FEV1) and FEV1/FVC racio) followed by quadriceps muscle strength (QMS). Two standardized Incremental Shuttle Walking Tests (ISWT) were performed with, at least, 30 minutes of resting between them, at the end of the session. Data collection followed the standardized order as described.

Procedures

Physical activity (PA) was assessed by the Physical Activity Index, a questionnaire developed by Telama et al. (1997)(28), whose application to the Portuguese population has been described previously by Ledent, et al. (1997)(29) and Mota and Esculcas (2002)(30). The questionnaire has five questions punctuated in a four points scale, but some questions allows 5 answers. Thus, the overall maximum score is 22. A PA index can be obtained to express the activity levels, by dividing the sample into different activity groups, according to the total sum. This procedure has already been validated (31). The subjects are grouped into four categories: the sedentary group (0-5 points); low active group (6-10 points); moderately active group (11-15 points) and vigorously active group (above 15 points) on the basis of their reported physical activity(29). Mota and Esculcas (2002)(30) assessed the test reliability and internal consistency in sample of Portuguese healthy children, and reported excellent values of test retest reliability (ICC =0.92 to 0.96) and a good internal consistency (α= .87).

Spirometry was performed using a portable spirometer (MicroLab Micro Medical 36-ML3500-MK8, UK). Spirometry is the most valuable and reproducible lung function test used in children(32-34).

Most 6 years old can perform the technique reliably, with some 5 years old also managing to perform it as well(35). However, it is possible that some children may present difficulties to perform the manoeuvres efficiently. In these cases, in the current era with the availability of better spirometry equipment with incentives and modified criteria for acceptability and repeatability, it is possible to perform reliable spirometry tests even in preschool children by trained personnel (32). Recent studies have demonstrated that most children can produce acceptable and repeatable spirometry values, according to international standardization(36). Spirometry was measured following the international guidelines(36), i.e., with the child in the up-right position and using a nose-piece to reduce the air leak. A short period of training before data collection was performed, for the children to adapt and be comfortable with the equipment and the operator. At least three manoeuvres were recorded and the best of three was considered for data analysis(34, 37).

Quadriceps Muscle Strength (QMS) was measured by using an isometric hand-held dynamometer (HHD) (MicroFet2 Hand Held dynamometer). This instrument have been developed to aid physiotherapists in clinics and to overcome the limitations of the manual muscle testing (MMT) (38). HHD is small and portable, with an ergonomic shape and light weight that makes it easy to use. Versatile attachments ensure proper muscle isolation for increased testing validity and measure strength objectively in kilograms, pounds or newtons. To measure QMS, the physiotherapist held the HHD between his or her hand and the patient's limb segment. During the manoeuvre, patient's encouragement to exert as much force against the device as possible, during 6 seconds, was given and the maximum force was recorded by the HHD(39, 40). In this study, the muscle group tested was measured in the sitting position (knee 90° flexed), with the dynamometer positioned in the anterior surface of distal shunt joint proximal to ankle joint and three measurements were made, with an interval of at least 30 seconds(41, 42). Test-retest reliability in hand-held dynamometer in healthy children has been reported by Stuberg et al. (1988)(43). In their study test-retest reliability correlation coefficients ranged from 0.74 to 0.99. In 1992 Brussock, et al.(44) reported a range from 0.85 to 0.98. This suggests that HHD can be used to measure force values in normal children adequately(41).

Exercise tolerance was measured with the ISWT which is commonly used - in clinical practice, by physiotherapist to identify the causes of decreased exercise tolerance, directing and monitoring the intervention more effectively. Modified versions of the ISWT have been applied to paediatric populations (<18 years) with asthma (22) and cystic fibrosis(23, 24), to assess their physical performance, however there are no reference equations that allow people to calculate the distance

travelled by children and healthy adolescents which would provide the normative pattern to compare against. ISWT (45) was conducted in a 10 meter course identified by two cones placed 0.5 meters from each end point. Participants walked (or run) around the course according to the speed dictated by an audio signal. The initial walking speed was 0.5 m/s and it increased by 0.17 m/s each minute; the speed increment was always indicated by a different sign. An adaptation of the modified protocol was used, that is, the audio signals continued until subjects reach their maximal effort, exceeding the 12 levels of speed proposed by the modified protocol. Also, subjects were allowed to run, if necessary. This protocol was already applied in healthy adults to avoid a ceiling effect since participants were healthy subjects and their maximal effort would probably exceed 12th level(25). The initial explanation was standardized and no encouraging phrases were given to the participants during the test. The ISWT was interrupted in case of participants presented one of the following conditions: could not maintain the required speed due to dyspnoea or fatigue; or if failed to complete a shuttle in the time allowed for the second time. Two incremental shuttle walking tests were performed with, at least, 30 min of resting between them(11). The best test, i.e., the longest walked distance covered by the child, was considered for analysis. The tests were executed by physiotherapists familiarized with the ISWT, and the two tests were conducted by the same evaluator. Several parameters were measured before and after the tests in a sitting position: Heart rate (HR) and Oxygen saturation using a pulse oximeter (Konica-minolta pulsox-300 pulsometer), arterial blood pressure with an automated sphygmomanometer (MARS-model MS-700AMI), perceived dyspnoea and leg fatigue with a modified Borg scale (mBS). In this study, dyspnoea was assessed with the mBS (45) associated with pictorial illustrations of increased dyspnoea to facilitate the children's understanding and interpretation of the scale (>5 years) (46, 47).

Participants performed these evaluations over the course of approximately two hours.

Statistical analysis

All data were inserted in the PASW Statistics version 22.0 for Windows (IBM Corp., Armonk, NY). Descriptive statistics were applied to characterise the sample (i.e., socio-demographic, anthropometric and clinical data). Data were described as mean ± standard deviation (SD) or as frequencies. The predicted maximal heart rate (HRmax) for each participant was calculated according to the formula of Gellish et al. (206.9-(0.67 x age))(48). The normality of data distribution was checked with Shapiro-Wilk tests. Chi-square tests for ordinal variables and independent

samples t-tests for continuous variables were used to compare the characteristics of male and female participants.

Paired t-test were used to compare results between the two ISWTs performed. Pearson correlation coefficients were calculated to study the variables that were most correlated with the ISWT. A model of multiple linear regression was applied (ISWT as dependent variable; demographic and anthropometric data as independent variables) to evaluate the best predictor variables for ISWT. To assess the performance of the model, R-squared (R^2) and ANOVA F-test were used(49). Based on the model achieved, a reference equation was built. A Bland & Altman plot was created to evaluate the agreement between the ISWT performed and the ISWT predicted value (GraphPad Prism version 5.01, GraphPad Software, Inc., La Jolla, CA, USA). The level of significance considered was set at $p< 0.05$.

Results

The study included 55 participants (n=29; 52.72% female). Participants' mean age was 13.73±2.48 years old; 6 (10.91%) were between 5-10 years old, 23 (41.82%) between 11-14 years old and 26 (47.27%) between 15-17 years old. Participants presented a normal body composition (BMI=21.08±3.76 Kg m^{-2}) and lung function (FEV_1 106.78±12.29% predicted). No significant differences were found between male and female for height, weight and physical activity scale. However, male participants presented significantly higher QMS (28.57±6.52 vs 22.14±4.97 kgf; $p<.001$). According to Beenaker, et al. (2001)(41), these QMS values are slightly lower than the reference values. Table 1 provides a detailed description of the sample.

Table 1 Characteristics of the sample.

Characteristics	Total (n=55)	Female (n=29)	Male (n=26)	Test	p-value
Age (years)	13.73±2.48	14.24±1.75	13.15±3.03	t=1.652	.104
Age groups n(%)					
5-10yrs	6 (10.91%)	1 (3.45%)	5 (19.23%)	X^2=3.520	.172
11-14yrs	23 (41.82%)	13 (44.83%)	10 (38.46%)		
15-17yrs	26 (47.37%)	15 (51.72%)	11 (42.31%)		
Educational level[a] n(%)					
Primary	4 (7.27%)	1 (3.45%)	3 (11.54%)	X^2=5.185	.075
Lower Secondary	3 (5.45%)	0 (0%)	3 (11.54%)		
Upper Secondary	48 (87.28%)	28 (96.55%)	20 (76.92%)		
Weight (kg)	55.82±14.16	56.79±13.26	54.73±15.29	t=.536	.594
Height (m)	161.44±13.31	160.93±8.87	162.00±17.14	t=-.295	.769
BMI (Kg m^{-2})	21.08±3.76	21.79±4.47	20.30±2.63	t=1.482	.144
PAS (total score)	15.82±3.49	16.14±3.26	15.46±3.77	t=.714	.478
Lung Function					
FEV_1 % pred	106.78±12.29	109.00±10.97	104.31±13.39	t=1.427	.159
FVC % pred	98.76±12.09	101.10±9.56	96.15±14.13	t=1.535	.131
FEV_1/FVC	92.22±5.67	93.90±5.65	90.35±5.17	t=2.421	.019*
QMS (kgf)	25.18±6.56	22.14±4.97	28.57±6.52	t=-4.137	<.001*

Data are expressed as mean± standard deviation unless otherwise indicated. P-value concern the difference between male and female participants. BMI: body mass index; PAS: physical activity scale; FEV_1: forced expiratory volume in the first second; FVC: forced vital capacity; QMS: Quadriceps Muscle strength

[a] According to the International Standard Classification of Education (ISCED).

* $p<0.05$

Incremental Shuttle Walking Test

In the first ISWT, participants walked on average 1189.27±343.93 meters and in the second ISWT 1196.00±355.71 meters (p=0.641) (table 2). Considering the best performance of the ISWT, participants walked on average 1233.82±348.86 meters, presenting large variability between individuals (range 340-2250 m). Twenty-three (42%) participants had their best performance in the first test, 31 (56%) in the second test and 1 (2%) performed the exact same distance in the two tests. During the best performance, participants reached 71% of their maximal predicted HR. Eighteen percent (n=10) of participants reached the 12th level of the protocol, and seventy-one

percent (n=39) exceeded the 12th level presenting a walked distance higher than 1020 m: 6 participants reached the 13th level; 12 reached the 14th level; 12 others reached the 15th level; 6 reached the 16th level; 2 reached the 18th level and 1 reached the 19th level. Male participants walked significantly further than female (1322.85±430.55 m vs. 1144.14±227.13 m; p=.043).

Table 2 Parameters of the two Incremental Shuttle Walking Tests (n=55).

Parameters	ISWT1	ISWT2	t-test	p-value
Number of Shuttles	118.82±34.51	119.38±35.90	-.412	.641
Level	13.35±2.41	13.44±2.40	-.896	.374
ISWT (m)	1189.27±343.93	1196.00±355.71	-.470	.682
Pre SBP (mmHg)	121.05±14.90	121.05±14.90		1
Post SBP (mmHg)	113.82±11.28	110.51±12.69	1.963	.055
Pre DBP (mmHg)	70.22±9.54	70.22±9.54		1
Post DBP (mmHg)	67.31±9.94	65.27±9.09	1.958	.055
%HR max (%)	71.45±13.16	68.39±15.09	2.157	.036*
Pre RR (bpm)	21.15±3.97	21.15±3.97		1
Post RR (bpm)	28.47±5.93	36.73±7.07	-8.012	<.001*
Pre SpO_2 (%)	97.96±1.37	97.96±1.37		1
Post SpO_2 (%)	97.04±1.59	97.02±1.77	.094	.925
Pre Dyspnoea (pts)[a]	0±.0	0±.0		1
Post Dyspnoea (pts)[a]	5.96±1.60	7.11±2.08	-6.410	<.001*
Pre Fatigue (pts)[a]	0	0		1
Post Fatigue (pts)[a]	7.27±1.67	7.78±2.28	-2.267	.027*

Data are expressed as mean±standard deviation unless otherwise indicated. ISWT: incremental shuttle walking test; HR: Heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; SpO2: Oxygen saturation; RR: respiratory rate.

[a] Assessed using the Modified Borg Scale

* $p<0.05$

ISWT determinants

There were significant correlations between the distance walked in the ISWT with gender (r=0.274; p=.043), age (r=0.659; p<0.001), weight (r=0.310; p=.021), height (r=0.646; p<.001), PAS (r=0.284;

p=.035), QMS (r=0.535; p<.001), but not with BMI (r=-0.026; p=.852) or with FEV_1 % predicted (r=0.152; p=.267). These correlations are presented in Table 3.

Table 3 Incremental Shuttle Walking Test determinants.

	Pearson r	p-value
Gender	.274	.043
Age (years)	.659	<.001
Weight (Kg)	.310	.021
Height (m)	.646	<.001
BMI (Kg m^{-2})	-.026	.852
PAS (total score)	.284	.035
FEV_1 % predicted	.152	.267
QMS (kgf)	.535	<.001

BMI: body mass index; PAS: physical activity scale; FEV_1: forced expiratory volume in the first second; QMS: quadriceps muscle strength.

Multivariate Linear Regression

A multivariate linear regression was performed using the variables from table 3 with p-values below 0.05. The regression model showed that gender, age, weight and quadriceps muscle strength explained 70% of the variability in the ISWT (R^2= 0.704; ANOVA p<0.001). Based on this model, the reference equation for the distance walked in the ISWT was:

$ISWT_{predicted}$=-699.69+(239.329*gender)+(134.616*age)-(9.941*weight)+(12.107*QMS)

(where female = 0 and male = 1)

A strong correlation (r=0.833; p<.001) was observed between the ISWT performed and the value predicted. The Bland & Altman plot shows a reasonable agreement between the ISWT performed and the predicted value obtained from the reference equation (Figure 1). A mean difference of 238.19±193.81 meters was found and the 95% limits of agreement ranged from -618.06 to 141.69 meters.

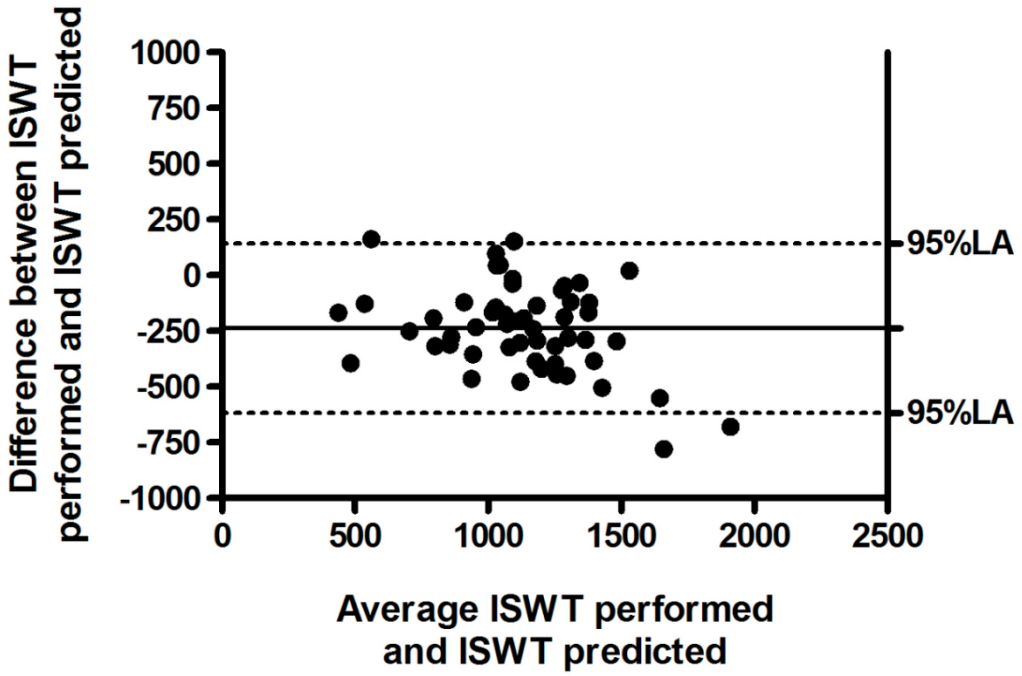

Figure 1 - Bland & Altman of the difference between the ISWT performed and the predicted value plotted against the mean of the ISWT performed and the predicted value. The bold line represents the mean difference and the dotted lines the 95% limits of agreement (95%LA).

Discussion

This study demonstrated that healthy participants aged from 5 to 18 years old present large variability in the ISWT (340-2250 m), and that 70% of this variance is explained by gender, age, weight and quadriceps muscle strength. Based on these findings, it was possible to establish a reference equation for predicting ISWT, which can be easily applied in clinical and research settings.

In this study, the demographic variables gender and age were independent predictors of ISWT performance. Males walked approximately 182 m further than females. Although no data is available for the paediatric population, these findings are in line with what has been described in

other studies involving the adult population(25, 50). Adult men present greater absolute muscle strength, muscle mass, height and ability to achieve higher levels of physical activity than women, which might explain the influence of gender on the distance walked during childhood and youth (5). No data concerning the correlation between age and the ISWD in paediatric population was found in literature. However, this influence has been found among adults (51, 52). In a study with 42 male participants, Pearce et al. (53), stated that age alone was associated with walking speed. Himann et al.(54), also found that age was the only significant independent predictor for walking speed when 438 participants aged 19-102 years walked over an 80 m indoor course. With the findings from the present study, it seems to be similar among the paediatric population.

In this study, anthropometric variables, height and weight, were also independent predictors of the ISWD. Previous correlations found between height/ISWD and weight/ISWD in other studies (25, 50) support the present results. These strong correlations can be attributed to the greater stride length in taller individuals, as stride length is a major predictor of gait speed (55, 56). Although height has been found to have good correlations in children performing the 6MWD (5), and in adults performing the ISWT (25, 50), this variable was not retained in the multiple regression model. This might be explained by the small age (14-16 years old) and height (1.22-1.80m) range in this study. Regarding to weight, the correlation between body weight and distance walked on field walk tests has been found to be weak or not significant in previous studies(57-60). However, the present results showed a significant and positive correlation between body weight and ISWD. This result may be due to the fact that the young people has less weight and were more active when compared with the adult population. On the other hand, results from the multiple regression analysis revealed a negative coefficient for body weight, which can be explained by the nonlinear relationship between body weight and walking performance (59). Obesity increases the workload of walking, resulting in a shorter distance walked by subjects with a higher body weight or BMI (61). Similar results were previously described in the literature for adolescents with obesity (61) and in patients with chronic obstructive pulmonary disease(62). The present findings reinforce these previous results.

The clinical variables retained as independent predictors of ISWD were FEV_1, PAS and QMS. Although significant correlations between ISWD and FEV_1 have been found in healthy males aged 40 to 69 years old(63) and between 6MWD and FEV_1 in populations with chronic pulmonary disease, namely, with cystic fibrosis(59, 64, 65), the results from this study, do not corroborate these findings (r=.152, p=.267). This may be due to the fact that FEV_1 and height are strongly correlated(5)

and in these study height was not included in the multiple regression analysis. A poor correlation between PAS and ISWD (r=.284 , p<0.05) was also observed. Although no similar data was found to corroborate these findings, others have also failed to demonstrate an association between self-reported physical activity and 6MWD in healthy adults(60, 66). QMS presented a moderate positive correlation with ISWD (r=.535, p<0.001), taking place in the reference equation. The literature presents conflicting information regarding this variable. In some research studying healthy older subjects, the QMS was not a predictor of the 6MWD (5, 66) whereas in another study the QMS had a non-linear relationship with gait speed (67). This means that the variability of gait speed depends upon determinants of performance besides strength that vary from person to person. The QMS values of this study were slightly lower than the reference values. However, this study did not involve a representative sample of the paediatric Portuguese population and the available reference values are also not Portuguese. Regardless of this, QMS brings us new information, and more detailed studies in Portuguese population should be conducted to better assess its role in ISWT performance.

This study proposed a reference equation of the ISWT for the healthy paediatric population. A reference equation for the healthy adult population has been published by a Brazilian research group (50). However, the multiple regression model was modest, explaining 50% of the variability, increasing the chance of bias in predicting the walking distance in the ISWT. Those authors considered for the statistical analysis only the second test instead of the test where the best performance was obtained. This procedure could have influenced the results since in the present study 42% of the participants had their best performance in the first test. Probst et al. (25), published, recently, an equation for the healthy adult population. Their study consisted of a sample of 242 participants aged between 18 to 83 years old. Their multiple regression model showed that gender, age and BMI were independent contributors, explaining 71% (p<0.001) of the variability of the ISWT and they also used the ISWT values related to the best performance.

Previous studies have shown that patients reach higher peak HR during the ISWT than during the 6MWT, characterizing the ISWT as a maximal exercise test(11, 68). In this study the peak HR was lower than those reported previously (11, 25, 50, 68), since participants only achieved 71% of their maximal predicted HR. This fact can be attributed to several factors: i) field walk tests depend on participants' motivation, even when an externally paced walk test such as the ISWT is undertaken; ii) the energy cost of walking is highly dependent on aspects related to the gait strategy such as the size and frequency of strides and degree of movement of the upper and lower limbs; iii) the

metabolic cost of running at low speed (i.e., jogging) is substantially greater than walking at a similar speed, indicating that, especially for the younger participants able to run more easily, it may have resulted in less cardiovascular stress (50, 65) . These aspects are important to be considered when prescribing exercise on a paediatric population based on ISWT performance. However, further investigation with a larger sample is needed.

Strengths and limitations

The use of a reference equation for the ISWT considering gender, age, weight and QMS allows interpreting the results adequately, taking into account each subject's characteristics, enabling more reliable intergroup comparisons and avoiding bias when using absolute values in the interpretation.

Some limitations of this study need to be acknowledged. First, the use of a small convenience sample is a major restriction, and therefore, these data is not representative of the paediatric Portuguese population. Although, caution was taken concerning the proportion of male and female subjects. Future studies should cover larger samples. Secondly, most of the subjects were between 14 and 16 years old, which is not representative of the lower ages. Future studies involving participants within the all paediatric age range are needed. Thirdly, the sample reached a lower HR in terms of % predicted of the maximal HR, suggesting a lower effort during the test. Thus, the values obtained in the ISWT may not reveal the real maximal capacity of the participants. Following this, standardization of the ISWT is necessary to ensure maximal effort during the test in order to avoid incorrect interpretation of results when considering reference values. Another limitation was that the measure of leg length was not measured and it could be an important predictor of ISWD because it is a primary determinant of stride length (69). Future studies including the measure of leg length are needed.

Conclusions

In summary, a contribution to establish reference values for the ISWT in the paediatric population was given. It can be concluded that variability in the performance of the incremental shuttle walking test in healthy paediatric population can be explained (70%) by using gender, age, weight and QMS. A reference equation was established based on these variables. Future research is needed in order

to establish definitive reference values for the ISWT in paediatric population. Standardization of the ISWT among the paediatric population is needed to ensure maximal effort during the test in order to avoid incorrect interpretation of results when considering reference values.

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Appendix I – Ethics' approval

COMISSÃO DE ÉTICA

da **Unidade Investigação em Ciências da Saúde - Enfermagem** (UICISA: E)

da **Escola Superior de Enfermagem de Coimbra** (ESEnfC)

Parecer Nº P186-10/2013

Título do Projecto: Estabelecimento de valores de referência para sons pulmonares adventícios e o teste de marcha com carga progressiva modificado em crianças saudáveis e com patologia respiratória

Identificação do Proponente

Nome(s): Alda Sofia Pires de Dias Marques; Ana Luísa Araújo Oliveira; Sara Sequeira Silva

Filiação Institucional: Escola Superior de Saúde da Universidade de Aveiro

Investigador Responsável/Orientador: Profª Alda Sofia Pires de Dias Marques

Relator: José Carlos Amado Martins

Parecer

Trata-se de estudo descritivo, correlacional, tendo como objetivo principal: "estabelecer valores de referência para os sons pulmonares adventícios e para o teste de marcha com carga progressiva em crianças com patologia respiratória e saudáveis, contribuindo assim para melhor compreensão das patologias, e consequentemente, melhorar o diagnóstico, monitorização e tratamento de crianças com problemas respiratórios".

Será utilizada amostra de conveniência, com crianças (idade<18 anos), com diagnóstico de patologia respiratória pediátrica e crianças saudáveis. Os critérios de inclusão/exclusão são definidos. Colheita de dados de dezembro de 2013 a dezembro de 2016.

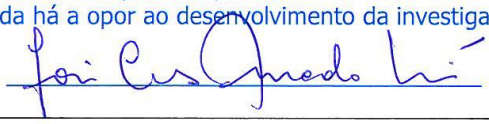
A caracterização decorrerá no Hospital Santa Maria (Porto), Banda Filarmónica Ovarense (Ovar), Clube do Povo de Esgueira (Aveiro) e Clínica Estrela Esteves Unipessoal (Aveiro), instituições com as quais existe protocolo de colaboração com a Universidade de Aveiro e que já aprovaram o estudo, sendo apresentados comprovativos.

São definidas as medidas e testes a utilizar que têm um carácter não invasivo.

É garantida a confidencialidade e o anonimato da informação em todo o processo de recolha e análise. Será solicitado o consentimento do responsável legal de cada criança e à própria criança, em função do seu grau de maturidade. São apresentados os documentos para informação e obtenção do consentimento na forma escrita, que cumprem os requisitos éticos.

Não são previstos desvantagens ou riscos para os participantes.

Tendo em consideração o exposto, é entendimento desta Comissão que, em termos éticos, nada há a opor ao desenvolvimento da investigação.

O relator: 

Data: 20/11/2013 O Presidente da Comissão de Ética: 

Appendix II – Institutions’ approval

Autorização Institucional

Eu, Hélio Armando Vieira Andrade

responsável pela instituição Escola Filarmónica Carlense

declaro que fui informado dos objetivos do estudo científico intitulado: "Estabelecimento de valores de referência para os sons pulmonares adventícios e o teste de marcha com carga progressiva modificado em crianças saudáveis e com patologia respiratória", e concordo em autorizar a execução da mesma nesta instituição. Caso necessário, a qualquer momento como instituição CO-PARTICIPNATE desta investigação poderemos revogar esta autorização, se comprovada atividades que causem algum prejuízo à esta instituição ou ainda, a qualquer dado que comprometa o sigilo da participação dos integrantes desta instituição. Declaro também, que não recebemos qualquer pagamento por esta autorização bem como os participantes também não receberão qualquer tipo de pagamento.

Hélio Armando Vieira Andrade	09-07-2013	
Representante da Instituição	Data	Assinatura
Sara Silva	09-07-2013	Sara Isabel Silva
Investigadora	Data	Assinatura

Annex I – Information sheets

Folha de informação ao encarregado de educação

As alunas Ana Luísa Araújo Oliveira e Sara Sequeira Silva, a frequentar o Mestrado em Fisioterapia da Escola Superior de Saúde da Universidade de Aveiro, sob a orientação científica da Professora Doutora Alda Sofia Pires de Dias Marques, vêm por este meio solicitar-lhe a autorização para a participação do seu educando no estudo clínico intitulado: "Estabelecimento de valores de referência para os sons pulmonares adventícios e o teste de marcha com carga progressiva modificado em crianças saudáveis e com patologia respiratória".

Mas, antes de decidir, é importante que compreenda porque é que a investigação está a ser realizada e o que é que a mesma envolve. Por favor, leia a informação com atenção e discuta a participação do seu educando, com outros se assim o entender. Se houver algo que não esteja claro para si ou necessitar de informação adicional, por favor não hesite em contactar as alunas ou a sua orientadora (contactos no final deste documento).

Muito obrigado desde já por ler a informação.

Qual é o propósito do estudo?

Este estudo visa estabelecer valores de referência para os sons pulmonares adventícios e para o teste de marcha com carga progressiva modificado em crianças com patologia respiratória e saudáveis (5-17 anos). Estes testes permitem uma avaliação objetiva e segura da condição cardio-respiratória de crianças sendo por isso largamente utilizado pelos fisioterapeutas para prescrever exercício físico em crianças com várias patologias como por exemplo, com asma e fibrose cística. No entanto, ainda não se encontram estabelecidos valores de referência que permitam diferenciar com segurança a normalidade das condições patológicas. Para que seja possível determinar estes valores de referência, venho então solicitar-lhe autorização para que o seu educando participe neste estudo que será realizado no Hospital de Santa Maria (Porto), Clinica Estrela Esteves Unipessoal, Lda (Aveiro), Cliria - Hospital Privado de Aveiro, SA e Banda Filarmónica de Ovar.

Porque foi o meu educando escolhido?

O seu educando foi escolhido porque se encontra a frequentar Banda Filarmónica de Ovar que deu permissão institucional para a realização do estudo e porque o seu educando não apresenta qualquer tipo de problema respiratório.

Tenho de aceitar a participação do meu educando?

A decisão de autorizar a participação do seu educando ou não é completamente sua. Se decidir autorizar vai-lhe ser pedido que assine dois formulários de consentimento informado, um para si e outro para as alunas de mestrado. No entanto, é totalmente livre de desistir a qualquer momento,

sem que para tal tenha de dar qualquer justificação. A decisão de desistir ou de não participar, não afetará a qualidade dos serviços de educação prestados ao seu educando agora ou no futuro.

O que acontecerá se autorizar a participação do meu educando?

Se decidir participar vai-lhe ser pedido que preencha o documento anexo a esta folha de informação relativamente aos problemas de saúde e medicação habitualmente utilizada pelo seu educando e que o entregue, bem como ao consentimento informado, ao docente que entrou em contacto consigo.

Após receber o consentimento informado devidamente assinado, as alunas dirigir-se-ão à instituição de educação do seu educando e procederão à aplicação do protocolo. Ser-lhe-á medido o peso e a altura, e realizar-se-á um teste muito simples para avaliar a sua capacidade de trazer o ar para fora dos pulmões, com um aparelho designado de espirómetro. Este teste consiste em soprar para um tubo, com a maior força possível. Ser-lhe-á também pedido que responda a um questionário de atividade física para avaliar as atividades físicas que o seu educando realiza dentro e fora da instituição.

De seguida, ser-lhe-á perguntado o quão difícil é para ele respirar, numa escala com diferentes graus de falta de ar. Depois, um oxímetro de pulso, equipamento semelhante a um relógio, ser-lhe-á colocado no pulso para medir a quantidade de oxigénio que o seu sangue está a transportar e a frequência cardíaca. De seguida, serão gravados os sons que os seus pulmões estão a fazer naquele momento, durante aproximadamente 20 segundos, com um estetoscópio digital ligado a um computador portátil. A força muscular dos membros inferiores também será medida através de um teste muito simples que consiste em realizar a extensão do joelho com a máxima força possível contra resistência de um aparelho chamado dinamómetro.

Depois de retiradas todas estas medidas, será realizado o teste de marcha com carga progressiva (modificado). Durante o teste será pedido ao seu educando que caminhe rapidamente, em velocidades crescentes, num percurso de 10 m delimitados por 2 cones (estando um cone em cada extremidade do percurso), que devem ser contornados pelo individuo. O oxímetro que lhe foi colocado, avaliará a saturação periférica de oxigênio (SpO_2) e a frequência cardíaca em intervalos 15 segundos para garantir que o teste decorre em total segurança. Após uma hora de repouso, repetir-se-á o teste. A aplicação do protocolo terá a duração de aproximadamente 30 minutos.

Nenhum destes testes provoca qualquer desconforto e serão realizados em horários compatíveis com as atividades educacionais, de forma a não afetar a o programa letivo de atividades.

Quais são os efeitos secundários dos procedimentos do estudo?

Não existem efeitos secundários de participar no estudo.

Quais são as possíveis desvantagens e riscos se resolver autorizar a participação do meu educando?

Não existem quaisquer desvantagens ou riscos de participar no estudo.

Quais são os possíveis benefícios se eu resolver autorizar a participação do meu educando?

Não existem benefícios diretos de participar no estudo. No entanto, a informação obtida neste estudo poderá ajudar a desenvolver valores de referência para um teste largamente utilizado na fisioterapia, permitindo uma melhor avaliação e monitorização de crianças com problemas respiratórios.

A participação será confidencial?

Toda a informação recolhida no decurso do estudo será mantida estritamente confidencial. Os dados recolhidos serão salvaguardados com um código e palavra-passe, para que ninguém os possa identificar. Apenas as alunas responsáveiss pelo projeto e a sua orientadora terão acesso aos dados.

O que acontecerá aos resultados do estudo?

Os resultados do estudo serão analisados e incorporados em dissertações de Mestrado e alguns serão publicados em Jornais e/ou conferências de finalidade científica. No entanto, em nenhum momento o seu educando será identificado.

Contacto para mais informações sobre o estudo

Se pretender obter mais informações sobre o estudo, pode telefonar ou escrever para:

Ana Oliveira, Sara Silva e Alda Marques

Escola Superior de Saúde da Universidade de Aveiro,

Universidade de Aveiro,

Campus de Santiago,

Edifício III, 3810-193, Aveiro

Telefone: 913937469, 234 247 113 ou 234 372 462

e-*mail: alao@ua.pt; sarassilva@ua.pt; amarques@ua.pt*

Muito obrigado por ter lido esta informação.

✂_____

Se pretender obter uma cópia de qualquer relatório ou publicação, por favor indique o seu contacto de e-mail no espaço seguinte:

_____

Annex II – Informed Consent

CONSENTIMENTO INFORMADO

Título do Projeto: Sons pulmonares adventícios em crianças saudáveis e com patologia respiratória

Nome da Orientadora: Prof. Doutora Alda Sofia Pires de Dias Marques

Nome da aluna de Mestrado: Sara Sequeira Silva

Por favor leia e marque com uma cruz (X) os quadrados seguintes.

1. Eu confirmo que percebi a informação que me foi dada e tive a oportunidade de questionar e de me esclarecer. ☐
2. Eu percebo a participação do meu encarregando é voluntária e que ele é livre de desistir, em qualquer altura, sem dar nenhuma explicação, sem que isso afete qualquer serviço de saúde que lhe é prestado. ☐
3. Eu compreendo que os dados recolhidos durante a investigação são confidenciais e que só os investigadores responsáveis pelo projeto têm acesso a eles. E dou portanto, autorização para que os mesmos tenham acesso a esta informação. ☐
4. Eu compreendo que os resultados do estudo serão publicados numa dissertação de mestrado e jornais e/ou conferências de finalidade científica sem que haja qualquer quebra de confidencialidade e anonimato. E dou portanto, autorização para a utilização dos dados para esses fins. ☐
5. Eu confirmo que o meu encarregando foi questionado acerca da sua vontade em participar no estudo e que nenhuma avaliação foi realizada contra a sua vontade, sendo assim respeitada a sua autonomia. ☐
6. Eu concordo então em participar no estudo. ☐

_____	_____	_____	_____
Nome do Participante	Representante Legal	Data	Assinatura

Annex III – Physical Activity Index

Questionário de Actividade Física

O presente questionário pretende identificar o nível de actividade física dos jovens, por isso, são-te postas questões sobre os teus hábitos de actividade física, mas não te preocupes em acertar ou errar, porque não existem respostas certas ou erradas. Procura ser sincero nas tuas respostas e, desde já, agradeço a tua colaboração.

QUESTÃO 1: Fazes parte de actividades desportivas extra-escola (num clube ou noutro sítio)? *Faz uma cruz no quadrado correspondente*

Nunca ☐ Menos de uma vez por semana ☐ Uma vez por semana ☐ Quase todos os dias ☐

QUESTÃO 2: Participas em actividades de lazer (ocupação do tempo livre) sem integrares um clube? *Faz uma cruz no quadrado correspondente*

Nunca ☐ Menos de uma vez por semana ☐ Uma vez por semana ☐ Quase todos os dias ☐

QUESTÃO 3: Para além das horas lectivas, quantas vezes praticas desportos durante, pelo menos, vinte minutos? *Faz uma cruz no quadrado correspondente*

Nunca ☐ Pelo menos uma vez por mês ☐ Entre uma vez por mês e uma vez por semana ☐ Entre 2 a 3 vezes por semana ☐

Entre 4 a 6 vezes por semana ☐ Todos os dias ☐

QUESTÃO 4: Fora do tempo escolar, quanto tempo por semana dedicas à prática de actividades desportivas ao ponto de ficares ofegante (respirar depressa e com dificuldade) ou transpirando? *Faz uma cruz no quadrado correspondente*

Nunca ☐ Entre meia-hora e uma hora ☐ Entre 2 a 3 horas ☐ Entre 4 a 6 horas ☐

Sete ou mais horas ☐

QUESTÃO 5: Participas em competições desportivas?

Faz uma cruz no quadrado correspondente

Nunca ☐ participei

Não participo, mas já participei ☐

Sim, a nível interescolar ☐

Sim, ao nível de um clube ☐

Sim, a nível nacional e/ou internacional ☐